

**NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
SMALL PLANETARY MISSION PLAN
REPORT TO CONGRESS
April 1992**

Washington, D.C.

INTRODUCTION

In the Senate Report accompanying H.R. 2519, the Fiscal Year 1992 VA, HUD, Independent Agencies Appropriations bill, the Committee on Appropriations directed NASA to prepare "a plan to stimulate and develop small planetary or other space science projects, emphasizing those which could be accomplished by the academic or research communities." This document outlines NASA's small planetary projects plan within the context of overall agency planning. In particular, this plan is consistent with Vision 21: The NASA Strategic Plan, and the Office of Space Science and Applications (OSSA) Strategic Plan.

Over the last 5 years, OSSA's strategic planning process has provided for the introduction and implementation of space science projects ranging from small missions that proceed from concept to flight in less than 3 years to large flagship missions that span a decade. Currently, most science disciplines are pursuing a balanced program of investigations with a flagship flight project as a cornerstone.

However, a change is occurring in the character of the space science program: the aggressive emergence of small missions. The current budgetary environment challenges NASA's ability to sustain a program of high science value and opportunity. As part of an overall approach to maintaining the vitality and progress of the science community, NASA is emphasizing the introduction of small projects in its near-term plans. The budget dictates that all missions be made as robust and responsive to likely budget fluctuations. Over the next several years, this emphasis will become apparent in the new initiatives NASA brings to the Congress for approval through the budgetary process.

Nowhere is this shift in attention to small missions more apparent than in NASA's Solar System Exploration Division (SSED). Two years ago, small planetary missions were just beginning to be discussed by the scientific community. Today they are the centerpiece of NASA's new programs for the 1990's. As illustrated by Figure 1, SSED has examined each element of the traditional approach to planetary exploration and developed an innovative, small project-oriented approach for more streamlined, cost-effective missions. Wherever possible, this method has been applied to develop new approaches to planned missions and to plan new missions. This document discusses several mission concepts that have been developed using the small projects approach.

In addition, new small robotic missions to the Moon, managed by NASA's Office of Exploration, are being proposed as part of the Space Exploration Initiative.

ATTRIBUTES OF SMALL PLANETARY MISSIONS

Small planetary projects address focused scientific objectives using a limited number of mature instruments, and are designed to require little or no new technology development. Small missions can be implemented by university and industry partnerships in coordination with a NASA Center to use the unique services the agency provides. The timeframe for small missions is consistent with academic degree programs, which makes them an

excellent training ground for graduate students and post-doctoral candidates. Because small missions can be conducted relatively quickly and inexpensively, they provide greater opportunity for increased access to space. In addition, small missions contribute to sustaining a vital scientific community by increasing the available opportunities for direct investigator involvement from just a few projects in a career to many.

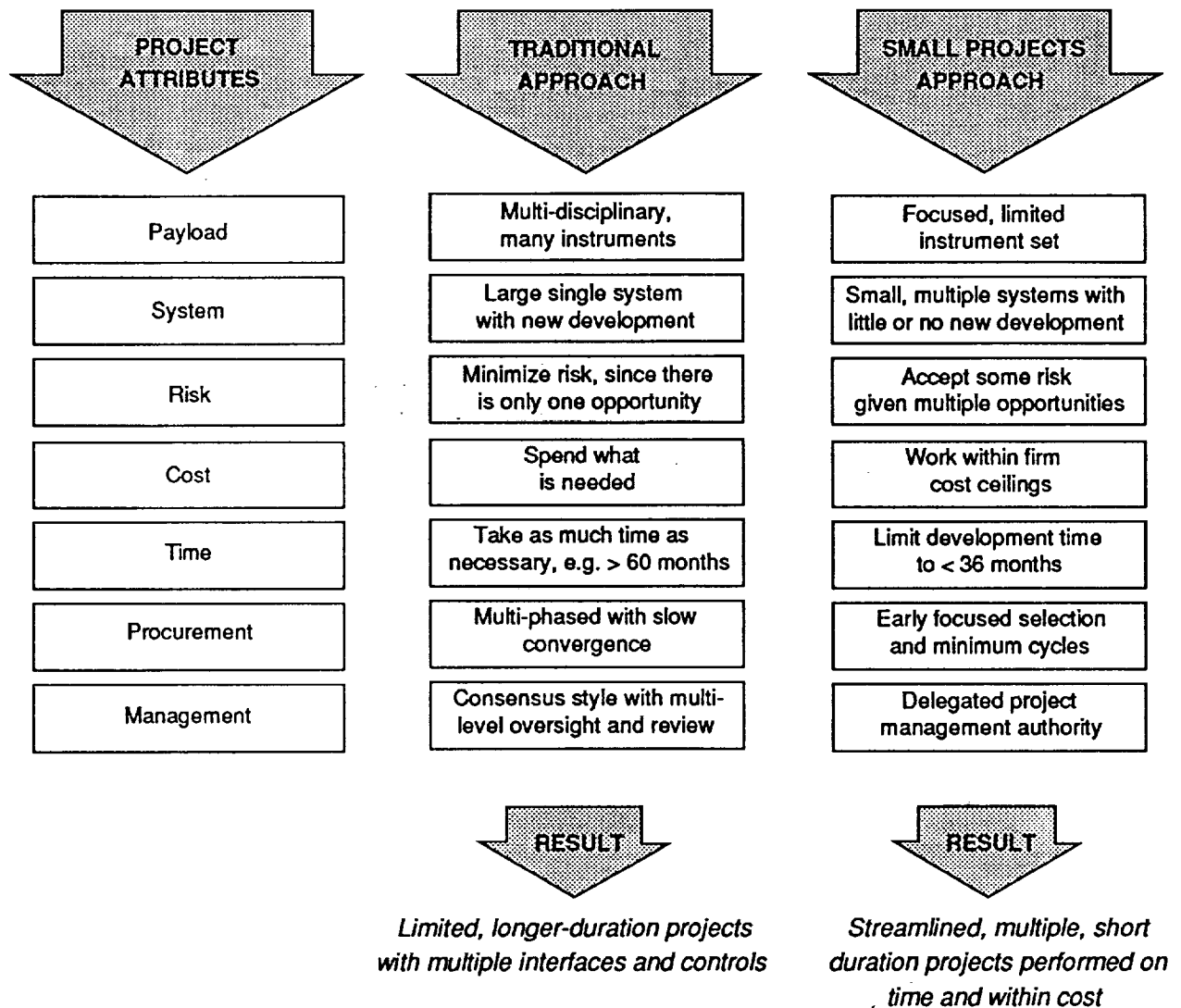


Figure 1. The Solar System Exploration Division has Developed an Alternative Small Projects Approach to Each Facet of its More Traditional Approach.

The planetary science community is entering another period of sustained planetary mission data with the success of the Magellan Venus mapping mission, the launch of the Mars Observer mission later this year, and the Galileo encounter with Jupiter in 1995. However, a significant gap exists between the end of Galileo's mission at Jupiter in 1998 and the beginning of Cassini's mission at Saturn, which is not scheduled to occur until well after the

turn of the century. Figure 2 illustrates how the proposed small projects discussed below -- Discovery, MESUR, and TOPS-0 -- are designed to sustain the flow of new data throughout this period.

Small missions have fixed cost ceilings and schedules, and are managed with considerably less oversight. NASA program office control is in the nature of assessing hardware and project readiness before approval and adherence to a strict implementation plan, with only ancillary technical support. Once the project is under way, a strong resistance to change must be present to contain cost growth. The small scales and short lifetimes of these projects permit them to be terminated if they grow out of scope.

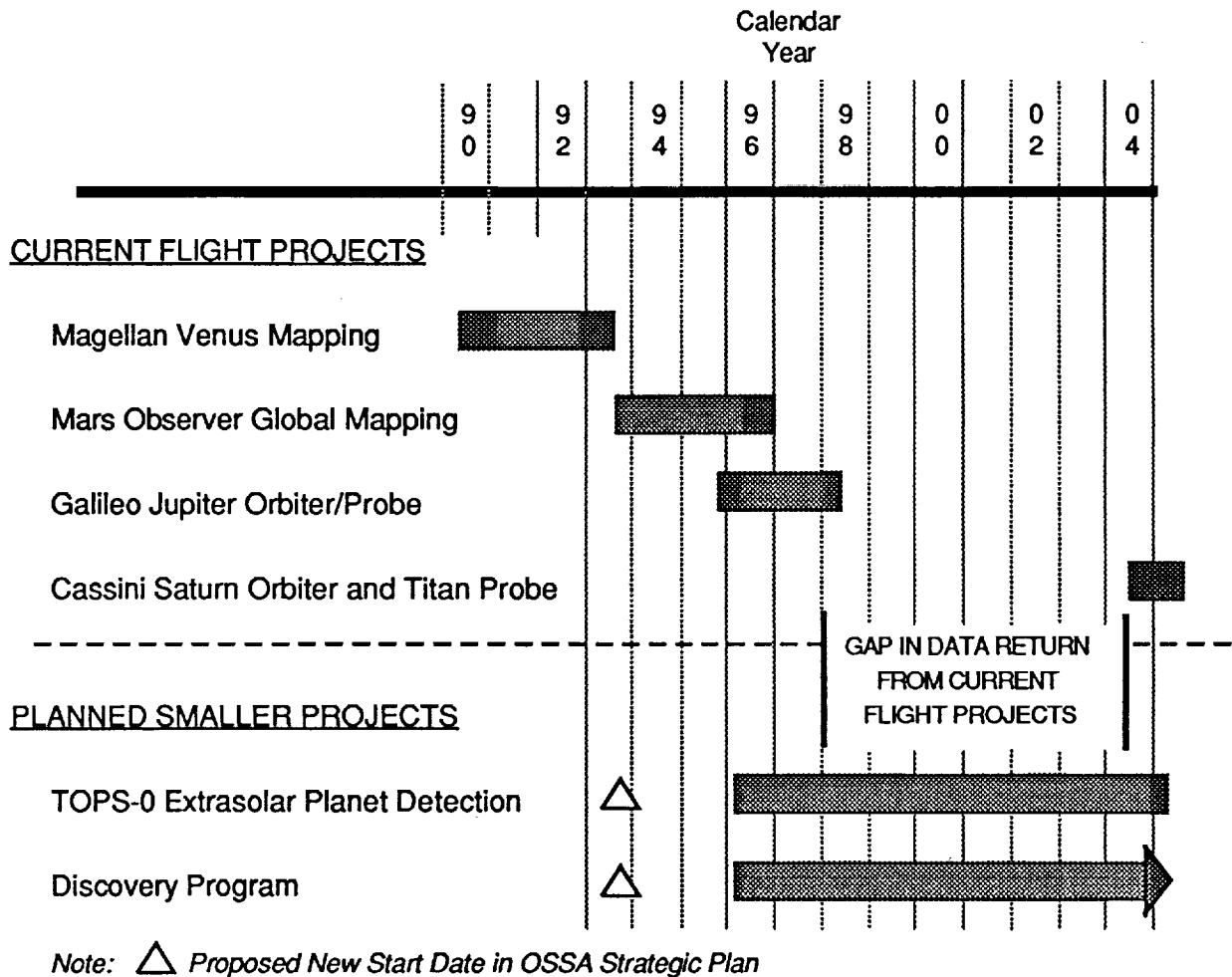


Figure 2. Planned Small Projects will Maintain a Steady Flow of New Data to Complement Approved Larger Missions.

SMALL PLANETARY PROJECT OPPORTUNITIES

The design concepts under review for future small planetary missions draw heavily on NASA's extensive experience with small- and moderate-sized spacecraft, especially the Explorer and Earth Probes programs. Both of these on-going NASA programs emphasize focused science objectives and streamlined management structures, enabling important advances in scientific knowledge. Since its inception, NASA has launched 66 Explorer spacecraft, covering most major disciplines within space science. Some of the more recent Explorer missions include the Cosmic Background Explorer (COBE) launched in 1989, which is revolutionizing our understanding of the early formation of the universe and the Infrared Astronomical Satellite (IRAS), launched in 1984, which provided the first all-sky survey of infrared radiation.

Explorer missions currently in development include the Extreme Ultraviolet Explorer (EUVE) scheduled for a 1992 launch, the X-ray Timing Explorer (XTE) which will follow in 1996, the Advanced Composition Explorer (ACE) planned for launch in 1997, and the Far Ultraviolet Spectroscopic Explorer (FUSE) which will fly early in the next century. NASA is also completing preparations for launch of the Solar, Anomalous, and Magnetospheric Particle Explorer (SAMPEX) later in 1992. SAMPEX was developed in under 3 years as the first Small-class Explorer (SMEX). The Earth Probes program was approved as a new start in the fiscal year 1991 budget. Missions under development include the Total Ozone Mapping Spectrometer (TOMS) scheduled for launch aboard a NASA Small Expendable Launch Vehicle (SELV) in 1993; a separate TOMS instrument will be launched on a Japanese H-II launch vehicle in 1996; the NASA Scatterometer (NSCAT) scheduled for launch in 1996; and the Tropical Rainfall Measuring Mission (TRMM) planned for launch in the 1996-97 timeframe.

NASA has identified several exciting, scientifically important small mission candidates. NASA also has developed an innovative small-spacecraft approach to establishing a comprehensive network of small landers on Mars. To illustrate the rich variety and scale of small project opportunities, we briefly describe the following two initiatives:

- (1) **Discovery**, a program concept under study that would involve developing a series of scientifically exciting, cost-effective missions that can be carried out with small spacecraft, small launch vehicles, a constrained instrument payload, and highly focused science objectives for inner solar system objects. Discovery management will be modelled on NASA's existing Explorer and Earth Probe programs. Total mission cost is not expected to exceed \$150 million, with an annual peak funding level of \$85 million (all figures cited are in Fiscal Year (FY)1992 dollars).
- (2) **Toward Other Planetary Systems (TOPS-0)**, a program concept under study that would consist of a combination of ground-based observations, scientific research, and technical developments, including the Keck II observatory, to search for, identify, and examine planets around other stars. The cost of this program through the current decade would be less than \$100 million.

In addition, the Office of Exploration will manage a lunar resources mapping mission and a lunar gravity-topography mission, both of which would feature small, inexpensive and quick concepts that would produce new lunar global scientific data sets while setting the stage for later human exploration. These missions are each characterized by a small instrument set (e.g. three), using off-the-shelf concepts or flight-proven instruments. The price range of these missions, including launch, is estimated at \$100 million each. There will be significant academic involvement in these missions, particularly in the analysis of data sets, which will far surpass existing lunar data in coverage and resolution.

Discovery. The Discovery Program is a planned initiative to develop and launch small planetary science missions. This program will emphasize focused science return achieved through mature instrument and spacecraft technology and implemented with a recognition that lower costs may imply the acceptance of a modest increase in the level of risk. Discovery Program management will be modelled after NASA's existing Explorer and Earth Probes programs.

Discovery flight projects will be planned to launch within 3 years from project start. Individual missions, or NASA's contribution to cooperative missions, are expected to cost no more than \$150 million, with an annual program expense level of no more than \$85 million. A significant number of important solar system investigations could fit within these cost and schedule guidelines. The benefits of the Discovery program include rapid response to emerging scientific opportunities, participation in cooperative ventures with other agencies, the timeline is more in-line with graduate degree programs and academic resources, increased breadth of activity in the solar system exploration program, and enhanced timeliness for new information return on important scientific questions.

One concept under study for the Discovery program is a small lander on the surface of Mars, to be launched in 1996. This lander, called MESUR (Mars Environmental Survey) Pathfinder, would demonstrate the technologies required for the MESUR multiple-lander program described below. Although MESUR is not part of the Discovery Program, a brief description of MESUR, which also uses small spacecraft, is helpful to understand MESUR Pathfinder.

MESUR would establish a global network of about 16 small stations on Mars to study the planet's meteorology, internal seismic activity, and local surface properties. MESUR uses small spacecraft, small launchers, and a sequential implementation plan that has the advantages of low cost and distributed risk. Each station is expected to weigh less than 150 kilograms, and all stations will be identical. These stations would be packaged into probes that can be launched on a single medium-class expendable launch vehicle in clusters of four, separated, and flown independently to preselected sites on Mars. An instrumented lander carried by each probe would descend to the surface by parachute. Additional clusters would be launched at two subsequent opportunities, spaced 26 months apart. Current medium-class ELV's are capable of launching a cluster of either four stations, or two stations and a communications orbiter. Using this approach, the MESUR program can be spread over several years at modest annual costs (less than \$150 million). The European Space Agency (ESA) is presently studying similar concepts for deployment in the same time period. An ongoing effort between NASA and ESA is seeking to define an effective cooperative strategy that would further reduce cost and programmatic risk for the MESUR mission. NASA and ESA are both seeking additional foreign partners to establish a truly international science network on the surface of Mars.

MESUR Pathfinder would demonstrate the technologies, flight systems, and cost-containment management approaches necessary for the MESUR mission. The MESUR Pathfinder lander would carry a prototype of the Mars microrover to be flown on later MESUR payloads. The microrover would in turn carry a camera and one or two additional scientific instruments. The lander would also carry instruments provided by NASA's Office of Exploration to search for subsurface ice and measure Martian soil toxicity. MESUR Pathfinder would provide a test of the Mars launch strategy, interplanetary transportation system, lander technology, and surface mobility approach before these systems were replicated for the 16-lander MESUR network mission. It would also provide important scientific information about Mars to aid in planning MESUR and subsequent landed missions.

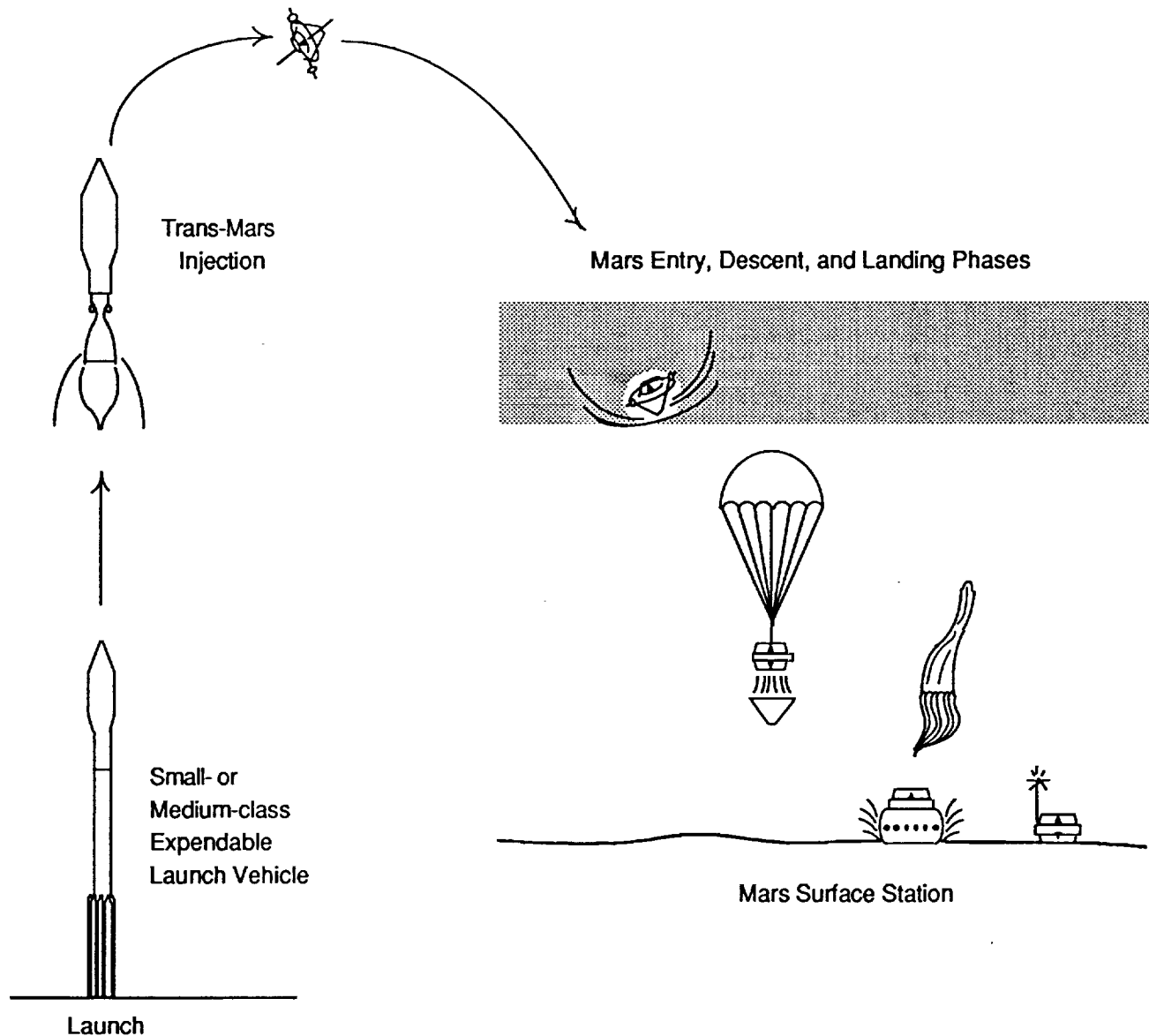


Figure 3. This Scenario for Emplacing a Mars Lander Reflects the New Small Project Approach

A second concept under study is a Near-Earth Asteroid Rendezvous (NEAR) mission. The NEAR spacecraft, probably carrying only three instruments, would spend up to a year station-keeping with a near-Earth asteroid. The mission would assess the asteroid's mass, size, density, and spin rate, map its surface topography and composition, determine its internal properties, and study its interaction with the interplanetary environment.

NASA recently commissioned parallel studies by the Jet Propulsion Laboratory and the Applied Physics Laboratory of the Johns Hopkins University to determine the feasibility of performing the NEAR mission with Discovery program small spacecraft design concepts.

Although the two studies produced significantly different designs, the results were comparable in mass and overall functional performance. The general assessment was that viable spacecraft concepts are available that would allow a Discovery-class near-Earth object rendezvous mission.

Other candidate Discovery missions include:

- Venus atmospheric probe to measure the isotopic abundances and vertical profiles of gases in the lower Venus atmosphere
- Earth-orbiting planetary ultraviolet telescope to study the magnetospheric/atmospheric couplings of the giant outer planet systems
- Multiple asteroid/comet flybys to expand the scientific reconnaissance of small bodies, using the NEAR instrument payload and flight system
- Mars aeronomy orbiter to address focused questions related to the chemistry, dynamics, and composition of the upper atmosphere, ionosphere, and magnetosphere of Mars
- Lunar scout missions, complementing the small lunar missions of the recently formed Office of Exploration, to complete a scientific orbital survey of the moon
- Phobos/Deimos rendezvous mission to determine the global physical properties and composition of these two moons of Mars using a NEAR-type spacecraft and science payload
- Comet reconnaissance missions, including a flythrough sample return developed collaboratively with Japan, to collect and return to Earth coma dust grains originating on the comet nucleus.

Toward Other Planetary Systems (TOPS-0). The TOPS-0 initiative is a small program concept under study that would address an exciting new area of planetary exploration and provide new vitality to our Nation's universities through investments in education, research, and related facilities. TOPS is planned as a three-step program focused on the discovery and physical study of planetary systems around other stars. TOPS-0, the reconnaissance phase, would start as a combination of ground-based observations, scientific research, and technical developments. The keystone of this phase will be NASA's contribution to the construction of a second 10-meter telescope at the Keck Observatory in Hawaii, and the subsequent use of both Keck telescopes to examine nearby stars. The Keck program also includes enhanced instrumentation and an interferometer project using the Keck telescopes and smaller "outrigger" telescopes. Several years' observations with these instruments could confirm (or deny) the existence of Jupiter-sized planets around stars within approximately 50 light-years of Earth. The considerable excitement generated within the science community by this program reflects the importance of addressing a critical question of solar system formation: is our solar system a unique occurrence, or is it one of many in the universe?

In exchange for its contribution to the construction of the Keck-II telescope, NASA would receive a one-sixth share of observing time at the entire Keck facility. NASA is coordinating this effort with the University of Hawaii and the California Association for Research Astronomy (CARA), a Caltech/University of California association responsible for the construction and operation of the observatory. NASA is also planning to expand its Origins of Solar Systems program to provide grants for sustaining research and observations related to the discovery and study of new planetary systems.

SMALL PLANETARY PROJECTS PLAN

NASA has defined and begun to implement a Small Planetary Projects Plan. Work on this plan has been in progress for more than a year, initially stimulated by the creation and structure of the present OSSA strategic planning process, which recognizes the important role of small projects. The Report of the Advisory Committee on the Future of the U.S. Space Program ("Augustine Report") further underscores the importance of this effort. The Augustine Committee urged "that universities, other organizations, and their investigator teams be used increasingly as 'prime' contractors for space research instruments and projects."

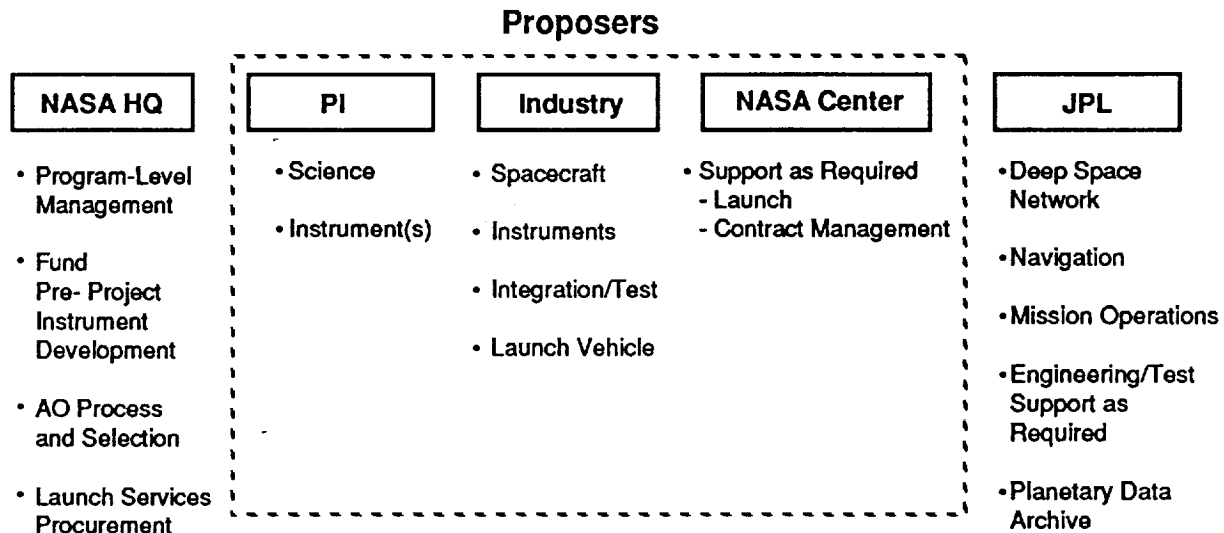


Figure 4. Roles and Responsibilities for Small Projects are Clearly Defined

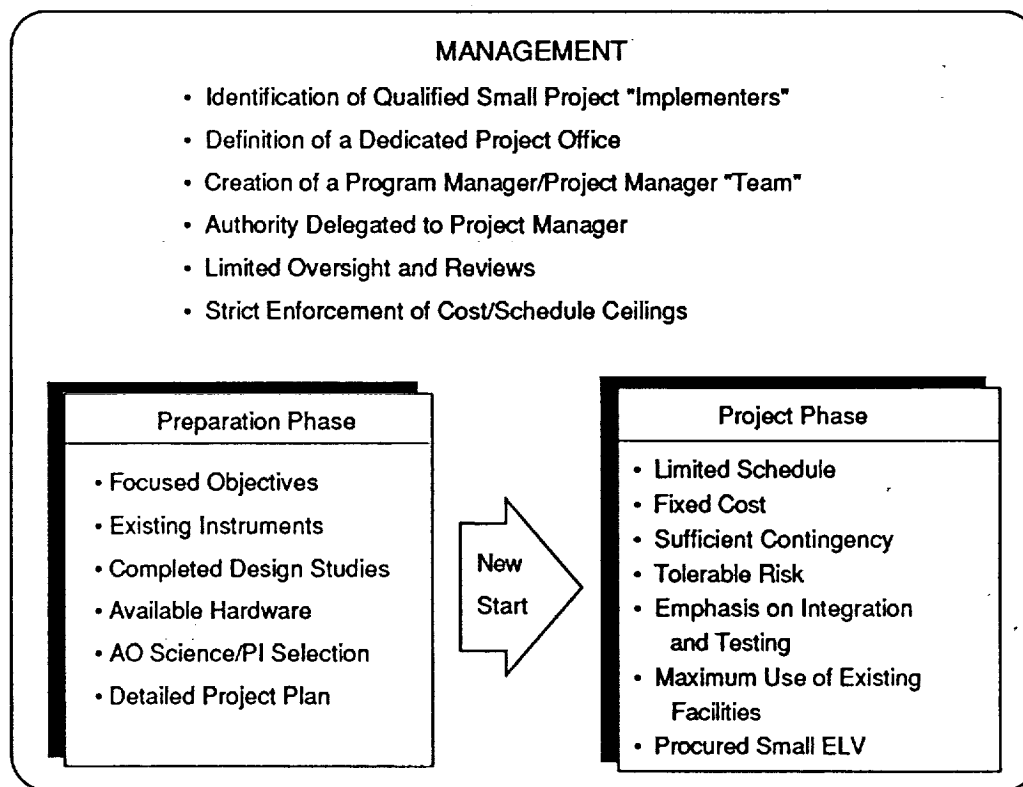
Encouraged by these actions and observations, our plan for small missions has taken shape with the following characteristics:

- Opportunities have focused, well-defined objectives, and use well-developed instruments and flight systems.
- Missions are implemented by qualified teams, preferably with substantial academic representation.
- Strictly observed ceilings will be set on cost, which must include reasonable contingencies.
- Risk will be tailored to each mission, generally at a level moderately higher than for larger projects.
- Project development time will be less than 3 years to ensure cost control and to maintain a steady flow of small projects within the overall program.
- Project oversight will be kept to a minimum, with implementation authority passed down to the Project Manager.
- The project procurement process will be streamlined to minimize the time and effort required to quickly establish each small mission project.

Using these characteristics and focusing on the Discovery Program, NASA has defined its approach for developing and operating small missions. The process begins with the definition of candidate concepts that meet small mission cost and schedule guidelines. This definition serves two purposes: identifying long-lead-time instrument development requirements, and stimulating the interest of industry and academia in developing these concepts into flight hardware. On the basis of scientific priority and concept readiness, a design is selected, and implementation is initiated. Procurement of selected Discovery concepts is expected to be performed using the existing Announcement of Opportunity process. Procurement will be at the flight project level with the selected consortia (academia and industry) of implementers given the responsibility to acquire or develop and integrate the science instruments and flight system based on their winning proposal. Figure 4 illustrates the expected roles and responsibilities of team members in Discovery and other small planetary projects.

Several activities were conducted during the past year to further refine the plan. A Discovery Program working group was formed with strong representation from the academic community to identify science objectives, instrument payloads, and candidate missions. A Discovery Cost and Management Team of Advisors was assembled to develop management and control principles for effective administration of small planetary projects. This team was made up of past planetary project managers, program managers, and individuals with direct experience in the development of fixed cost spacecraft. Their recommendations are summarized in Table 1.

Table 1. A Cost and Management Team of Advisors Made These Recommendations for Small Planetary Projects Management.



Near-term activities associated with the Small Planetary Projects Plan include the preparation of new start proposals and further planning. Both of these activities will draw on the \$10 million requested by the President in Fiscal Year 1993 for small planetary project development. NASA plans to work with the science community to determine the priority of TOPS-0, MESUR Pathfinder, and NEAR.

NASA will continue to seek new candidate small projects. Emphasis will be on developing additional Discovery missions and on the study of scientifically focussed, small missions to the outer planets. Outer planet concepts will have to have strictly limited scientific objectives to meet small mission cost criteria. These studies will involve academia and independent research institutions so that their interests and capabilities can continue to be appraised.

SUMMARY

NASA shares the Committee's view of the importance of small planetary projects. We are well along in small project development and are paying particular attention to the involvement of the University and independent Research & Development communities. We intend to implement small planetary projects as soon as possible, consistent with good preparation, sound management practices, and within available resources. Cost containment of these initiatives will make small projects a viable, enduring element of the overall space science program. We intend to rigorously enforce our cost objectives so that as many opportunities as possible will be realized by a community of qualified and enthusiastic scientists and engineers. These small projects can afford timely new opportunities to many investigators and institutions of our science community, fill in important gaps in our planetary exploration program, and revitalize educational interest in the space sciences.

#